DISCHARGE LAMP AND LAMP UNIT

BACKGROUND OF THE INVENTION

The present invention relates to a discharge lamp and a lamp unit. In particular, a discharge lamp and a lamp unit used as a light source for an image projection apparatus such as a liquid crystal projector and a digital micromirror device (DMD) projector.

In recent years, an image projection apparatus such as a liquid crystal projector and a DMD projector has been widely used as a system for realizing large-scale screen images, and a high-pressure discharge lamp having a high intensity has been commonly and widely used in such an image projection apparatus. In the image projection apparatus, light is required to be concentrated on a very small area of a liquid crystal panel or the like, so that in addition to high intensity, it is also necessary to achieve nearly a point light source. Therefore, among high-pressure discharge lamps, a short arc type ultra high pressure mercury lamp that is nearly a point light and has a high intensity has been noted widely as a promising light source.

Referring to Figs. **8A** to **8C**, a conventional short arc type ultra high pressure mercury lamp **1000** will be described.

Fig. **8A** is a schematic top view of a lamp **1000**. Fig. **8B** is a schematic side view of a lamp **1000**. Fig. **8C** is a cross-sectional view taken along line c-c′ of Fig. **8A**.

The lamp **1000** includes a substantially spherical luminous bulb **110** made of quartz glass, and a pair of sealing portions (seal portions) **120** and **120′** made of also quartz glass and connected

to the luminous bulb **110**. A discharge space **115** is inside the luminous bulb **110**. A mercury **118** in an amount of the enclosed mercury of, for example, 150 to 250mg/cm^3 as a luminous material, a rare gas (e.g., argon with several tens kPa) and a small amount of halogen are enclosed in the discharge space **115**.

A pair of tungsten electrodes (W electrode) **112** and **112'** are opposed with a certain gap in the discharge space **115**, and a coil **114** is wound around the end of the W electrode **112** (or **112'**). An electrode axis **116** of the W electrode **112** is welded to a molybdenum foil (Mo foil) **124** in the sealing portion **120**, and the W electrode **112** and the Mo foil **124** are electrically connected by a welded portion **117** where the electrode axis **116** and the Mo foil **124** are welded.

The sealing portion **120** includes a glass portion **122** extended from the luminous bulb **110** and the Mo foil **124**. The cross-sectional shape of the sealing portion **120** is circular, as shown in Fig. **8C**. In the sealing portion **120**, the glass portion **122** and the Mo foil **124** are attached tightly so that the airtightness in the discharge space **115** in the luminous bulb **110** is maintained. The principle of the reason why the luminous bulb **110** can be sealed by the sealing portion **120** will be briefly described below.

Since the thermal expansion coefficient of the quartz glass constituting the glass portion **122** is different from that of the molybdenum constituting the Mo foil **124**, the glass portion **122** and the Mo foil **124** are not integrated. However, by plastically deforming the Mo foil **124**, the gap between the Mo foil **124** and the glass portion **122** can be filled. Thus, the Mo foil **124** and

the glass portion **122** are attached to each other, and the luminous bulb **110** can be sealed with the sealing portion **120**. In other words, the sealing portion **120** is sealed by attaching the Mo foil **124** and the glass portion **122** tightly for foil-sealing. Since the glass portion **122** and the electrode axis **116** of the W electrode **112** are not attached tightly to each other, a gap (not shown) is generated between the glass portion **122** and the electrode axis **116** by a difference in the thermal expansion coefficient.

The Mo foil **124** attached to the glass portion **122** of the sealing portion **120** has a rectangular planar shape, and is positioned in the center of the sealing portions **120** and **120'**, as shown in Fig. **8C**. The Mo foil **124** includes an external lead (Mo rod) **130** made of molybdenum on the side opposite to the side on which the welded portion **117** is positioned. The Mo foil **124** and the external lead **130** are welded to each other so that the Mo foil **124** and the external lead **130** are electrically connected at a welded portion **132**. The external lead **130** is electrically connected to a member (not shown) positioned in the periphery of the lamp **1000**.

Next, the operational principle of the lamp **1000** will be described. When a start voltage is applied to the W electrodes **112** and **112'** via the external leads **130** and the Mo foils **124**, discharge of argon (Ar) occurs. Then, this discharge raises the temperature in the discharge space **115** of the luminous bulb **110**, and thus the mercury **118** is heated and evaporated. Thereafter, mercury atoms are excited and become luminous in the arc center between the W electrodes **112** and **112'**. As the pressure of the mercury vapor of the lamp **1000** is higher, the emission efficiency is higher,

so that the higher pressure of the mercury vapor is suitable as a light source for an image projection apparatus. However, in view of the physical strength against pressure of the luminous bulb **110**, the lamp **1000** is used at a mercury vapor pressure of 15 to 25MPa.

As a result of in-depth research, the inventors of the present invention found that the lifetime of the conventional lamp **1000** is shortened by the fact that the sealing structure of the sealing portions **120** is destroyed.

More specifically, the cross-sectional shape of the sealing portions **120** of the lamp **1000** is circular, so that the length of the sealing portion **120** in the thickness direction is constant (in other words, the thickness of the glass portion **122** of the sealing portion **120** is constant). In addition, since the sealing portion **120** is sealed by the attachment between the Mo foil **124** and the glass portion **122**, as shown in Figs. **9A** and **9B**, an internal stress **40** (from the glass portion **122**) occurs uniformly on the Mo foil **124** in the direction perpendicular to the surface of the foil (the **Z** direction in Figs. **9A** and **9B**). For this reason, as shown in Fig. **9C**, when expansion and contraction of the Mo foil **124** are repeated with use of the lamp **1000**, the gap **119** between the glass portion **122** on the luminous bulb **110** side and the electrode axis **116** proceeds in the direction shown by an arrow **119a** (i.e., the longitudinal direction of the Mo foil **124**) between the glass portion **122** and the Mo foil **124** that are simply attached. When the gap **119** proceeds and reaches the welded portion **132** between the Mo foil **124** and the external lead **130**, the entire Mo foil **124**

is oxidized. Thus, the conductivity of the Mo foils **124** is lost, so that the lamp **1000** stops its operation.

To deal with compactness of the lamp size corresponding to compactness of image projection apparatuses, reducing the size of the sealing portion **120** is in demand. To meet this demand, when the size of the sealing portion **120** is reduced, as shown in Fig. **9B**, the thickness **T** of the glass between the side face **124a** of the Mo foil **124** and the surface **122a** of the glass portion **122** becomes small. Therefore, a crack **45** proceeding from the side face **124a** of the Mo foil **124** reaches the surface **122a** of the glass portion **122**, so that the sealing structure of the sealing portion **120** can be destroyed.

SUMMARY OF THE INVENTION

Therefore, with the foregoing in mind, it is a main object of the present invention to provide a discharge lamp having a long lifetime in which the sealing structure of the sealing portions can be maintained for a long period.

A discharge lamp of the present invention includes a luminous bulb in which a luminous material is enclosed and a pair of electrodes are opposed in the luminous bulb; and a pair of sealing portions for sealing a pair of metal foils electrically connected to the pair of electrodes, respectively; wherein at least one of the pair of sealing portions is provided with at least one constricted portion whose length in a thickness direction of the metal foil in the sealing portion is smaller than that of other portions in the sealing portion.

It is preferable that at least one of the constricted portions is provided in a portion on the luminous bulb side than a center of the sealing portion.

It is preferable that a plurality of constricted portions are formed on the sealing portion.

Furthermore, it is preferable that each of the pair of metal foils includes an external lead on a side opposite to a side electrically connected to a corresponding electrode of the pair of electrodes, and at least one of the constricted portions is formed in an area between an end of the electrode and an end of the external lead of at least one of the sealing portions.

According to another aspect of the present invention, a discharge lamp includes a luminous bulb in which a luminous material is enclosed and a pair of electrodes are opposed in the luminous bulb; and a pair of sealing portions for sealing a pair of metal foils electrically connected to the pair of electrodes, respectively; wherein at least one of the pair of sealing portions is provided with at least one oblate cross-section portion in which a length in a direction perpendicular to a thickness direction of the metal foil in the sealing portion is larger than that in the thickness direction in the sealing portion.

In one embodiment, the cross-sectional shape of the oblate cross-section portion is a substantially ellipse having a minor axis in the thickness direction of the metal foil and a major axis in a direction perpendicular to the thickness direction.

It is preferable that the oblate cross-section portion is provided in a portion on the luminous bulb side than a center of

the sealing portion.

It is preferable that the oblate cross-section portion is formed in the entire sealing portion.

It is preferable that each of the pair of sealing portions has a shrink seal structure.

It is preferable that the ends of the pair of sealing portions on a side opposite to the luminous bulb side are tapered.

In one embodiment, each of the pair of metal foils is attached tightly to a glass portion extended from the luminous bulb, and each of the pair of metal foils is a molybdenum foil.

In one embodiment, the luminous material comprises at least mercury.

A lamp unit of the present invention includes the above-described discharge lamp and a reflecting mirror for reflecting light emitted from the discharge lamp.

A method for producing a discharge lamp of one embodiment of the present invention includes (a) preparing a pipe for a discharge lamp including a luminous bulb portion for a luminous bulb for a discharge lamp and a side tube portion extending from the luminous bulb portion; and an electrode assembly including a metal foil, an electrode connected to the metal foil, and an external lead connected to the metal foil on a side opposite to a side connected to the electrode; (b) inserting the electrode assembly into the side tube portion so that an end of the electrode is positioned inside the luminous bulb portion; (c) attaching the side tube portion to the metal foil by reducing a pressure in the pipe for a discharge lamp and heating and softening the side tube

portion after the step (b); and (d) forming a constricted portion in the side tube portion. In one embodiment, the step (d) is performed by pulling the side tube portion to the external lead side.

Hereinafter, the functions of the present invention will be described.

According to a discharge lamp of the present invention, a constricted portion whose length in the thickness direction of the metal foil is smaller than that of other portions in the sealing portion is formed in the sealing portion. Therefore, the internal stress (from the glass portion) to the surface of the metal foil in the sealing portion in the constricted portion can be smaller than that in the other portions. For this reason, the internal stress from the metal foil in the constricted portion can be relatively larger than that in the other portions, so that the metal foil can be deformed (thermally expanded) selectively in the constricted portion. As a result, the metal foil in the constricted portion can stop the gap from proceeding in the sealing portion. Thus, compared with the prior art, the sealing structure of the sealing portion can be maintained for a long time. If the constricted portion is provided in a portion on the luminous bulb side than the center of the sealing portion, the proceeding of the gap in the sealing portion can be stopped more effectively. It is preferable to form a plurality of constricted portions, because the proceeding of the gap in the sealing portion can be stopped in a plurality of points. Furthermore, when the constricted portion is formed in an area between the end of the electrode and

the end of the external lead of the sealing portion, it is possible to avoid reduction of the connection strength between the electrode and the metal foil and the connection strength between the external lead and the metal foil.

Another discharge lamp of the present invention is provided with a portion having an oblate cross-sectional shape (hereinafter, referred to as "oblate cross-section portion") in which the length in the direction perpendicular to the thickness direction of the metal foil in the sealing portion is larger than that in the thickness direction. This makes it difficult for a crack proceeding from the side face of the metal foil to reach the surface of the sealing portion over the prior art. As a result, the sealing structure of the sealing portion can be maintained for a long time over the prior art. The cross-sectional shape of the oblate cross-section portion can be, for example, a substantially elliptic shape having its minor axis in the thickness direction of the metal foil and its major axis in the direction perpendicular to the thickness direction. Cracks are likely to occur on the luminous bulb side in which the temperature is changed significantly, so that when the oblate cross-section portion is provided in a portion on the luminous bulb side than the center of the sealing portion, the sealing structure of the sealing portion can be prevented from being destroyed by cracks effectively. Furthermore, for example, the cross-sectional shape of the entire sealing portion is a substantially elliptic shape and the entire sealing portion can be constituted by the oblate cross-section portion.

It is preferable that each of the pair of sealing portions

has the shrink seal structure to improve the resistance to pressure. Examples of the discharge lamp of the present invention include a mercury lamp comprising at least mercury as a luminous material (including ultra high pressure mercury lamp, high pressure mercury lamp and low pressure mercury lamp). The discharge lamp of the present invention can form a lamp unit in combination with a reflecting mirror.

According to a discharge lamp of the present invention, at least one of a pair of sealing portions has the constricted portion, so that the sealing structure of the sealing portion can be maintained for a long time, and the lifetime of the lamp can be prolonged. According to another discharge lamp of the present invention, at least one of a pair of sealing portions has the oblate cross-section portion, so that the sealing structure of the sealing portion can be maintained for a long time, and the lifetime of the lamp can be prolonged.

This and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. **1A** is a schematic top view showing a structure of a discharge lamp **100** of Embodiment **1**.

Fig. **1B** is a schematic side view showing a structure of a discharge lamp **100** of Embodiment **1**.

Fig. **1C** is a cross-sectional view taken along line c-c′ of

Fig. **1A**.

Fig. **1D** is a schematic enlarged view showing the shape of an end face of a metal foil **24**.

Fig. **2** is an enlarged cross-sectional view showing a constricted portion of a sealing portion.

Figs. **3A** to **3C** are cross-sectional views of a process sequence for illustrating a method for producing the discharge lamp **100** of Embodiment **1**.

Fig. **4** is a cross-sectional view for illustrating a method for producing a discharge lamp **200** of Embodiment **1**.

Fig. **5A** is a schematic top view showing a structure of a discharge lamp **300** of Embodiment **2**.

Fig. **5B** is a schematic side view showing a structure of a discharge lamp **300** of Embodiment **2**.

Fig. **5C** is a cross-sectional view taken along line c-c' of Fig. **5A**.

Fig. **6** is a cross-sectional view of a process sequence for illustrating a method for producing the discharge lamp **300** of Embodiment **2**.

Fig. **7** is a schematic view showing a structure of a lamp unit **500** of Embodiment **3**.

Fig. **8A** is a schematic top view showing a structure of a conventional discharge lamp **1000**.

Fig. **8B** is a schematic side view showing a structure of a discharge lamp **1000**.

Fig. **8C** is a cross-sectional view taken along line c-c' of Fig. **8A**.

Figs. **9A** and **9B** are views for illustrating the problems of the conventional discharge lamp **1000**.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, embodiment of the present invention will be described with reference to the accompanying drawings. In the following drawings, the elements having substantially the same functions bear the same reference numeral.

Embodiment 1

A discharge lamp **100** of Embodiment **1** of the present invention will be described with reference to Figs. **1** to **4**.

First, Figs. **1A** to **1D** are referred to. Fig. **1A** is a schematic top view showing a discharge lamp **100** of Embodiment **1**. Fig. **1B** is a schematic side view showing the discharge lamp **100**. Fig. **1C** is a cross-sectional view taken along line c-c′ of Fig. **1A**. Fig. **1D** is a schematic enlarged view showing the shape of an end face of a metal foil **24**. The arrows **X**, **Y** and **Z** in Figs. **1A** to **1D** show the coordinate axes.

The discharge lamp **100** of Embodiment **1** includes a luminous bulb **10**, and a pair of sealing portions **20** and **20′** connected to the luminous bulb **10**.

A discharge space **15** in which a luminous material **18** is enclosed is provided inside the luminous bulb **10**. A pair of electrodes **12** and **12′** are opposed to each other in the discharge space **15**. The luminous bulb **10** is made of quartz glass and is substantially spherical. The outer diameter of the luminous bulb **10** is, for example, about 5mm to 20mm. The glass thickness of

the luminous bulb **10** is, for example, about 1mm to 5mm. The volume of the discharge space **15** in the luminous bulb **10** is, for example, about 0.01 to 1.0cc. In this embodiment, the luminous bulb **10** having an outer diameter of about 13mm, a glass thickness of about 3mm, a volume of the discharge space **15** of about 0.3cc is used. As the luminous material **18**, mercury is used. For example, about 150 to 200mg /cm^3 of mercury, a rare gas (e.g., argon) with 5 to 20kPa, and a small amount of halogen are enclosed in the discharge space **15**. In Figs. **1A** and **1B**, mercury **18** attached to the inner wall of the luminous bulb **10** is schematically shown.

The pair of electrodes **12** and **12′** in the discharge space **15** are arranged with a gap (arc length) of, for example, about 1 to 5mm. As the electrodes **12** and **12′**, for example, tungsten electrodes (W electrodes) are used. In this embodiment, the W electrodes **12** and **12′** are arranged with a gap of about 1.5mm. A coil **14** is wounded around the end of each of the electrodes **12** and **12′**. The coil **14** has a function to lower the temperature of the electrode end. An electrode axis (W rod) **16** of the electrode 12 is electrically connected to the metal foil **24** in the sealing portion **20**. Similarly, an electrode axis **16** of the electrode **12′** is electrically connected to the metal foil **24′** in the sealing portion **20′**.

The sealing portion **20** includes a metal foil **24** electrically connected to the electrode 12 and a glass portion **22** extended from the luminous bulb **10**. The airtightness in the discharge space **15** in the luminous bulb **10** is maintained by the foil-sealing between the metal foil **24** and the glass portion **22**. In other words, the

sealing portion **20** is a portion foil-sealed by the metal foil **24** and the glass portion **22**. The metal foil **24** is a molybdenum foil (Mo foil), for example, and has a rectangular shape, for example. The glass portion **22** is made of quartz glass, for example.

As shown in Fig. **1D**, the thickness **d** of the metal foil **24** is about 20 μm to 30 μm. The width **w** of the metal foil **24** is for example, about 1.5mm to 2.5mm. The ratio of the thickness **d** to the width **w** is about 1: 100. In this embodiment, as shown in Fig. **1D**, the side of the metal foil **24** is sharp. This design is adopted to prevent a gap from being generated between the metal foil **24** and the glass portion **22** and the internal stress occurring perpendicularly to the side face of the metal foil **24** from being directed to a direction x (X direction) perpendicular to the thickness direction of the foil as much as possible, so that cracks are prevented from occurring in the direction x (X direction) perpendicular to the thickness direction as much as possible.

It is preferable that the sealing portion **20** has a shrink seal structure for the following reason. In production of the sealing portion of the shrink seal structure, after the glass tube is heated and sealed, self-cooling is performed. Therefore, the residual stress (strain) is prevented from occurring in the glass portion **22** of the sealing portion **20**, and thus the resistance to sealing pressure can be improved. The metal foil **24** of the sealing portion **20** is joined with the electrode **12** by welding, and the metal foil **24** includes an external lead **30** on the side opposite to the side where the electrode **12** is joined. The external lead **30** is made of, for example, molybdenum. This design of the sealing

portion **20** applies to the sealing portion **20′**, so that further description is omitted.

At least one sealing portion **20** of the pair of sealing portions includes at least one constricted portion **26**. The constricted portion **26** is a portion whose length in the thickness direction (**Z** direction) of the metal foil **24** of the sealing portion **20** is smaller than that of other portions of the sealing portion **20** (e.g., a portion adjacent to the constricted portion **26**). In other words, in the constricted portion **26**, the thickness of the glass portion **22** in the thickness direction of the metal foil **24** is smaller than that of the other portions. As shown in Fig. **1B**, the constricted portion **26** is depressed from the portions adjacent to the constricted portion **26**, and the length **L′** of the constricted portion **26** in the thickness direction (**Z** direction) is shorter than the length **L** of the other portions in the sealing portion **20**. The length **L′** of the constricted portion **26** in the thickness direction can be, for example, 70 to 90% of the length **L** of the other portions.

In the area of the sealing portion **20** in which the metal foil 24 is disposed, the constricted portion **26** is a portion in which the contour of the sealing portion **20** is depressed and then the length in the thickness direction is increased from that of the depressed portion. Therefore, as shown in Fig. **1C**, when the cross-sectional shapes of the sealing portion **20** and the constricted portion **26** are circular, the outer diameter of the constricted portion **26** is smaller than that of the other portions.

In this embodiment, the outer diameter of the constricted portion **26** is, for example, about 7mm, and the outer diameter of

the portions other than the constricted portion **26** is, for example, about 8mm. In order to make it difficult for cracks proceeding from the side face **24c** of the metal foil **24** to reach the surface **26a** of the constricted portion **26**, it is preferable that the thickness **T** of the glass portion **22** from the side face **24c** of the metal foil **24** to the surface **26a** of the constricted portion **26** is, for example, about 2mm or more. The cross-sectional shape of the constricted portion **26** is not limited to a circle, and it can be for example, substantially an ellipse. Furthermore, in the discharge lamp **100** of the present invention, one sealing portion **20** has one constricted portion **26**, and the other sealing portion **20'** has a plurality of constricted portions **26**.

Next, Figs. **2A** and **2B** are referred to. Figs. **2A** and **2B** are schematic enlarged views showing the constricted portion **26** of the sealing portion **20**.

As shown in Fig. **2A**, when the sealing portion **20** has the constricted portion **26**, the internal stress **40** applied from the glass portion **22** perpendicularly to the metal foil **24** can be smaller in the constricted portion **26** than that in the other portions. This is because in the constricted portion **26**, the thickness of the glass portion **22** is smaller than that of the other portions, so that the stress applied from the glass portion **22** to the metal foil **24** is smaller than that of the other portions. Therefore, as shown in Fig. **2B**, since the internal stress **40'** applied from the metal foil **24** to the glass portion **22** is relatively larger in the constricted portion **26** than that in the other portions, the metal foil **24** is deformed, as shown by an arrow **24d**, and an

expanded portion **24e** is generated in the metal foil **24** in the constricted portion **26**. As a result, the expanded portion **24e** of the metal foil **24** can stop the gap **19** from proceeding in the direction of an arrow **19a**, and the entire metal foil **24** is prevented from being oxidized. In other words, the sealing structure of the sealing portion can be maintained for a long time over the prior art by allowing the metal foil **24** positioned in the constricted portion **26** to act as a portion for stopping gap proceeding **24e**.

It is preferable that the constricted portion **26** is formed in an area between the end **12e** of the electrode **12** and the end **30e** of the external lead **30** of the sealing portion **20** (glass portion **22**) for the following reason. When the constricted portion **26** is formed in this area, the constricted portion **26** is positioned in a portion other than the welded portions between the electrode **12** and the external lead **30** and the metal foil **24**. Therefore, it is possible to avoid reduction of the connection strength between the electrode **12** and the metal foil **24** and the connection strength between the external lead **30** and the metal foil **24**.

It is preferable to form the constricted portion **26** on the side connected to the luminous bulb **10** than the center of the sealing portion **20**, as shown in Figs. **1A** and **1B**, for the following reason. Since the proceeding of the gap **19** starts from the luminous bulb **10** side, the proceeding of the gap **19** can be stopped in an earlier stage. For example, it is sufficient that at least a part of the bottom face of the constricted portion **26** is positioned in a portion on the luminous bulb **10** side from the midpoint of the metal foil **24** along the longitudinal direction (**Y** direction) of the sealing

portion **20** (glass portion **22**). Furthermore, it is more preferable to form a plurality of constricted portions **26**, as in the sealing portion **20'**, because the proceeding of the gap **19** can be stopped at a plurality of points.

In this embodiment, both of the pair of sealing portions have the constricted portion **26**. However, when at least one sealing portion has the constricted portion **26**, the proceeding of the gap **19** can be stopped and the sealing structure of the sealing portion can be maintained for a long time over the prior art. For example when the discharge lamp **100** is set to a reflecting mirror, the constricted portion **26** can be formed only in the sealing portion on the side of the direction to which light exits (on the side of the front opening of the reflecting mirror) where significant temperature change occurs.

Next, a method for producing the discharge lamp **100** will be described with reference to Figs. **3A** to **3C**. Figs. **3A** to **3C** are cross-sectional views showing each process in a method for producing the discharge lamp **100**.

First, as shown in Fig. **3A**, the metal foil (Mo foil) **24** having the electrode **12** and the external lead **30** is inserted in a glass pipe for a discharge lamp having a portion for the luminous bulb **10** (luminous bulb portion) and a portion (side tube portion) for the glass portion **22** of the sealing portion (electrode insertion process). The metal foil **24** provided with the electrode **12** and the external lead **30** is referred to as "electrode assembly". It is preferable that the glass pipe for a discharge lamp used in this embodiment is made of high purity quartz glass comprising

a very low level, for example, several ppm or less, preferably, 1ppm or less each of alkali impurities (Na, K, Li) in order to prevent blackening and devitrification in the luminous bulb effectively. However, the present invention is not limited thereto.

Then, as shown in Fig. **3B**, the pressure in the glass pipe is reduced (e.g., one atmospheric pressure or less), and the glass tube **22** is heated and softened, for example, with a burner **50**, so that the glass tube (side tube portion) **22** and the metal foil **24** are attached so that the sealing portion **20** is formed (sealing portion formation process). At this time, in the state where the metal foil **24** and the glass tube (glass portion of the sealing portion **20**) **22** are not attached yet, the sealing portion **20** is pulled in the direction of an arrow **52**. Thus, a constriction is formed in the glass portion **22**, so that the constricted portion **26** is formed in the sealing portion **20**, as shown in Fig. **3C** (constricted portion formation process). Thus, the discharge lamp **100** provided with the sealing portion **20** having the constricted portion **26** can be produced. When the glass tube **22** is heated and softened while the glass tube **22** is standing in the vertical direction, the glass tube 22 is extended by the weight of the glass tube **22** itself. In this manner, the constricted portion 26 can be formed easily by utilizing gravity.

The constricted portion **26** can be formed in the following manner as well. The entire metal foil **24** and the side tube portion **22** are attached to each other, and a portion in which a constriction is desired to be formed is heated and melted selectively. Then,

the side tube portion **22** is pulled to the direction of the arrow **52** (the direction of the external lead side). Alternatively, after a portion in which a constriction is desired to be formed is heated and melted selectively, the portion is pinched so that the constricted portion **26** is formed.

Furthermore, as shown in Fig. **4**, after the constricted portion formation process, the glass portion **22** is further processed so that an end **20a** of the sealing portion **20** is tapered. In this manner, a discharge lamp **200** can be produced. When the end **20a** of the sealing portion **20** is tapered, the angle of the edge of the end **20a** is changed from 90 degrees to an obtuse angle. Therefore, in the process of handling a plurality of discharge lamps (for example, in a washing process or the like), the edge of the end **20a** of a discharge lamp is prevented from physically destroying a part of another discharge lamp (e.g., the glass portion **22** of the sealing portion **20**), or that possibility is reduced. The taper angle θ of the end **20a** of the sealing portion **20** can be for example, about 45 to 60 degrees.

In order to produce the tapered end **20a**, for example, the glass portion **22** is ground with a grinder **44** while rotating the glass pipe provided with the constricted portion in the direction of an arrow **46**. After grinding the glass portion **22**, the ground portion of the glass is broken, for example, by hand with a care not to break the external lead **30**, and an unnecessary portion **23** is removed. Thus, the discharge lamp **200** can be obtained.

In the discharge lamp of this embodiment, at least one of the pair of sealing portions has the constricted portion **26**, and

the metal foil **24** positioned in the constricted portion **26** can act as the gap proceeding stop portion **24e**. As a result, the sealing structure of the sealing portion can be maintained for a long time over the prior art.

<u>Embodiment 2</u>

A discharge lamp **300** of Embodiment **2** of the present invention will be described with reference to Figs. **5A** to **5C**. The discharge lamp **300** of this embodiment is different from the discharge lamp **100** of Embodiment **1** provided with the sealing portion having the constricted portion **26**, in that an oblate cross-section portion is formed in the sealing portion in Embodiment **2**. For simplification of description of this embodiment, the points different from Embodiment **1** will be described in the following description, and description of the same points are either omitted or simplified.

Fig. **5A** is a schematic top view of the discharge lamp **300** of this embodiment. Fig. **5B** is a schematic side view of the discharge lamp **300**. Fig. **5C** is a cross-sectional view taken along line c-c′ of Fig. **5A**.

The discharge lamp **300** of Embodiment **2** includes a luminous bulb **10**, and a pair of sealing portions **20** and **20′** connected to the luminous bulb **10**. At least one of the pair of sealing portions **20** and **20′** has at least one oblate cross-section portion **28**. In the oblate cross-section portion **28**, the length **L1** in the direction **x** (or the **X** direction in Figs. **5A**) perpendicular to the thickness direction of the metal foil **24** in the sealing portion **20** is larger

than the length **L2** in the thickness direction (the **Z** direction in Fig. **5B**). In this embodiment, the entire sealing portion **20** (or **20'**) is constituted by the oblate cross-section portion **28**, and as shown in Fig. **5C**, the cross-sectional shape of the oblate cross-section portion **28** has a substantially elliptic shape. In other words, the substantially elliptic oblate cross-section portion **28** having its minor axis **28b** in the thickness direction of the metal foil **24** and its major axis **28a** in the direction **x** perpendicular to the thickness direction is formed in the entire sealing portion **20**.

When the sealing portion **20** has the oblate cross-section portion **28**, the thickness **T** of the glass portion **22** from the side face **24c** of the metal foil **24** to the surface **28c** of the oblate cross-section portion **28** can be larger than that of a conventional discharge lamp having the same size. For this reason, it is difficult for cracks proceeding from the side face **24c** of the metal foil **24** to reach the surface **28c** of the oblate cross-section portion **28**. As a result, the sealing structure of the sealing portion can be maintained for a long time over the prior art.

Furthermore, compared with the case where the cross-section of the sealing portion **20** is circular, the ratio of the length **L2** in the thickness direction to the length **L1** in the direction **x** perpendicular to the thickness direction can be small. Therefore, the internal stress applied from the glass portion **22** to the upper and lower surfaces of the metal foil **24** can be relatively small. Thus, the metal foil **24** is more likely to be deformed in the thickness direction, and the internal stress of the metal foil **24** can be

stronger in the thickness direction. As a result, the internal stress applied from the side face **24c** of the metal foil **24** to the glass portion **22** (internal stress from the metal foil **24** in the direction **x** perpendicular to the thickness direction) can be smaller than that of the case of the circular cross-section. Therefore, in the case of the sealing portions **20** having the same thickness **T** of the glass portion **22** from the side face **24c** of the metal foil **24** to the surface **28c** of the oblate cross-section portion **28**, the substantially elliptic sealing portion **20** of this embodiment can maintain the sealing structure for a longer time than the sealing portion having a circular cross-section.

In this embodiment, as shown in Fig. **5C**, the oblate cross-section portion **28** is constituted to have a cross-section having its minor axis **28b** in the thickness direction of the metal foil **24** (**Z** direction in Fig. **5C**) and its major axis **28a** in the direction **x** perpendicular to the thickness direction (**X** direction in Fig. **5C**). The ratio of the length (**L1**) of the major axis **28a** to the length (**L2**) of the minor axis **28b** is for example, 2:1. When **L1** is about 16mm and **L2** is about 8mm, the thickness **T** of the glass portion **22** from the side face **24c** of the metal foil **24** to the surface **28c** of the oblate cross-section portion **28** is about 6mm in this embodiment.

Furthermore, even if the oblate cross-section portion is not formed in the entire sealing portion **20**, the sealing structure of the sealing portion **20** can be maintained for a long time over the prior art, as long as the oblate cross-section portion **28** is formed in at least a part of the sealing portion **20**. During operation

of a lamp, a temperature change in the metal foil **24** is larger in a portion close to the luminous bulb **10** than that in a portion away from the luminous bulb **10**, and therefore deformation (thermal expansion) of the metal foil occurring due to a temperature change is larger on the luminous bulb **10** side. As a result, cracks are likely to occur in the glass portion **22** on the luminous bulb **10** side. Therefore, when the oblate cross-section portion **28** is to be formed in a part of the sealing portion **20**, it is preferable to form the oblate cross-section portion **28** in the luminous bulb **10** side than the center of the sealing portion **20**. The constricted portion **26** of Embodiment **1** can be constituted as the oblate cross-section portion **28**, or the constricted portion **26** and the oblate cross-section portion **28** can be formed independently in the sealing portion **20**.

In this embodiment, both of the pair of sealing portions have the oblate cross-section portion **28**. However, it is sufficient to form the oblate cross-section portion **28** in at least one of the pair of sealing portions to maintain the sealing structure of the sealing portion for a long time over the prior art.

Next, a method for producing the discharge lamp **300** will be described. To obtain the discharge lamp **300**, after the electrode insertion process (Fig. **3A**) of Embodiment **1** is performed, the sealing portion formation process (Fig. **3B**) is performed so that the length **L1** of the direction (**X** direction) perpendicular to the thickness direction is larger than the length **L2** of the thickness direction (**Z** direction). Hereinafter, the method will be described more specifically with reference to Fig. **6**.

First, a glass pipe for a discharge lamp is disposed in a vertical direction (the **Y** direction in Fig. **6**), and then the upper portion and the lower portion of the glass pipe are supported with a chuck (not shown) so that the glass pipe can be rotated in the direction of the arrow **41**. Next, the metal foil **24** having the electrode **12** and the external lead **30** is inserted in the glass pipe, and then the glass pipe is put to be ready for pressure reduction. Then, the pressure in the glass pipe is reduced (e.g., 20kPa), and the glass pipe is rotated in the directions shown by the arrow **41**, and then the glass tube **22** is heated and softened by, for example, a burner **50**.

In this case, the glass tube **22** and the metal foil **24** are attached while changing the heating state between the glass portion **22** positioned in the thickness direction of the metal foil **24** and the glass portion **22** positioned in the direction (**X** direction) perpendicular to the thickness direction by temporarily stopping the rotation of the glass pipe or adjusting the rotation speed. In this manner, the oblate cross-section portion **28** is formed in the sealing portion **20**. In this embodiment, the oblate cross-section portion **28** is formed by temporarily stopping the rotation of the glass pipe in the position where the surface of the metal foil **24** faces the burner **50** (the rotation is stopped at every 180°). Alternatively, the oblate cross-section portion **28** can be formed by heating and softening a desired portion of the glass tube **22** by rotating the burner **50** without rotating the glass pipe.

In the discharge lamp of this embodiment, the sealing portion

has the oblate cross-section portion **28**, so that it is difficult for cracks proceeding from the side face **24c** of the metal foil **24** to reach the surface of the sealing portion **20**. As a result, the sealing structure of the sealing portion can be maintained for a long time over the prior art.

Embodiment **3**

The discharge lamps of Embodiments **1** and **2** can be combined with a reflecting mirror to form a lamp unit. Fig. **7** is a schematic cross-sectional view of a lamp unit **500** including the discharge lamp **100** of Embodiment **1**.

The lamp unit **500** includes the discharge lamp **100** including a substantially spherical luminous portion **10** and a pair of sealing portions **20** and a reflecting mirror **60** for reflecting light emitted from the discharge lamp **100**. The discharge lamp **100** is only illustrative, and any one of the discharge lamps of the above embodiments can be used. The lamp unit **500** may further include a lamp house holding the reflecting mirror **60**.

The reflecting mirror **60** is designed to reflect the radiated light from the discharge lamp **100** so that the light becomes, for example, a parallel luminous flux, a condensed luminous flux converged on a predetermined small area, or a divergent luminous flux equal to that emitted from a predetermined small area. As the reflecting mirror **60**, a parabolic reflector or an ellipsoidal mirror can be used, for example.

In this embodiment, a lamp base **55** is attached to one of the sealing portion **20** of the discharge lamp **100**, and the external

lead **30** extending from the sealing portion **20** and the lamp base **55** are electrically connected. The sealing portion **20** attached with the lamp base **55** is adhered to the reflecting mirror **60**, for example, with an inorganic adhesive (e.g., cement) so that they are integrated. A lead wire **65** is electrically connected to the external lead **30** of the sealing portion **20** positioned on the front opening side **60a** of the reflecting mirror **60**. The lead wire **65** extends from the external lead **30** to the outside of the reflecting mirror **60** through an opening **62** for a lead wire of the reflecting mirror **60**. For example, a front glass can be attached to the front opening **60a** of the reflecting mirror **60**.

Such a lamp unit can be attached to an image projection apparatus such as a projector employing liquid crystal or DMD, and is used as the light source for the image projection apparatus. The discharge lamp and the lamp unit of the above embodiments can be used, not only as the light source for image projection apparatuses, but also as a light source for ultraviolet steppers, or a light source for an athletic meeting stadium, a light source for headlights of automobiles or the like.

Other embodiments

In the above embodiments, mercury lamps employing mercury as the luminous material have been described as an example of the discharge lamp of the present invention. However, the present invention can apply to any discharge lamps in which the airtightness of the luminous bulb is maintained by the sealing portion (seal portion). For example, the present invention can apply to

discharge lamp enclosing a metal halide such as a metal halide lamp.

In the above embodiments, the mercury vapor pressure is about 20MPa (in the case of so-called ultra high pressure mercury lamps). However, the present invention can apply to high-pressure mercury lamps in which the mercury vapor pressure is about 1 MPa, or low-pressure mercury lamps in which the mercury vapor pressure is about 1 kPa. Furthermore, the gap (arc length) between the pair of electrodes **12** and **12′** can be short, or can be longer than that. The discharge lamps of the above embodiments can be used by any lighting method, either alternating current lighting or direct current lighting.

The invention may be embodied in other forms without departing from the spirit or essential characteristics thereof. The embodiments disclosed in this application are to be considered in all respects as illustrative and not limiting. The scope of the invention is indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.